WORLD WEATHER WATCH

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Each nation of the world — whether large or small, developed or developing — whatever its national characteristics and activities — whatever its geographical location on the earth's surface — shares with all other nations a common interest in the weather.

This interest in weather can however only be translated into useful knowledge by international collaboration, for the weather moves across the earth's surface without regard to national boundaries and barriers. Thus, over the last century or so, a world system for studying the weather has been developed for the common good. But modern scientific and technological developments — notably earth-orbiting meteorological satellites and high speed computers — now make possible a bold new approach to world meteorology.

The nations of the world have not been slow to recognize this new opportunity. In 1960 their representatives in the General Assembly of the United Nations adopted unanimously a resolution calling upon the World Meteorological Organization to develop a plan which will ensure :

— that these new devices are fully used in man's constant endeavour to improve his basic knowledge of the atmosphere, and

— that this knowledge will be applied in practical and peaceful ways for the benefit of all peoples of the world.

The response of the World Meteorological Organization to this challenging request has been the formulation of a plan for a new world weather system to which the name World Weather Watch has been given.

What sort of plan does World Weather Watch involve ?

Why do we need a plan ?

What are the benefits which the nations of the world may expect to derive ?

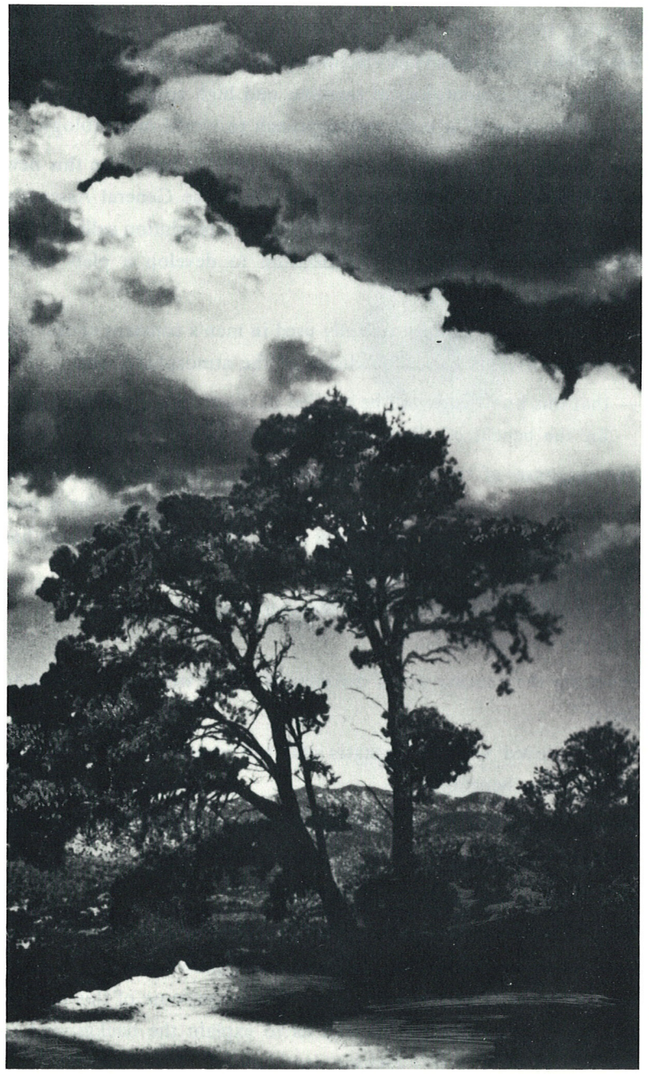
Will improved weather forecasts and will weather modification be among these benefits ?

In what ways will World Weather Watch assist economic development ?

Why does it need to be a *world* system ?

These are the sort of questions which will be increasingly asked as World Weather Watch becomes more well known and as the plans now being prepared become reality. It is the purpose of this booklet to answer such questions as well as to explain the background to the development of this exciting new concept. It is important that

such information should be generally available because directly or indirectly World Weather Watch will in due course affect each one of us — probably individually and certainly collectively; also, while each country will enjoy the benefits which World Weather Watch will present, each country will at the same time have an active role to play in its implementation and day-to-day operation. Indeed, it could hardly be otherwise in a project of such scale and complexity.



WEATHER CONCERNS EVERYBODY — AND ALL NATIONS

Man's environment is the atmosphere. Those atmospheric phenomena, which we call weather and climate have an all-pervading influence on human affairs ; they have to be accepted and, at present, they cannot be significantly changed by man. Agriculture, water resources, health, transportation and many other basic fields of human endeavour are influenced if not controlled by weather and climate. Indeed there is scarcely any human activity which is not affected in some way. The day-to-day effects of weather concern us all individually. Sometimes the effects are of a minor character ; sometimes they involve a great toll in life and property.

Although man has been exposed throughout the ages to the vagaries of the weather and has been forced to adapt his life and habits to them, it is strange to recall that only in relatively modern times has it been realized that weather systems move. They may change their form as they move ; thus a particular storm as it moves may become more intense or less intense — and the problem of forecasting the weather is essentially one of predicting the movement of weather systems and the way in which they will change as they move. It is for this reason that weather forecasting is only possible if up-to-date weather information is available over a large area surrounding the place for which the forecast is required. It is for the same reason that weather can only be effectively studied on an international basis and by collaboration between all nations.

To provide the means of effecting such collaboration the International Meteorological Organization was created in 1873 ; in 1951 it became the World Meteorological Organization, a specialized agency of the United Nations. The long history of the International Meteorological Organization is interesting and in many ways remarkable — but this story is told elsewhere.

Man is an inquisitive creature and from the earliest days of civilization his dependence on the weather has made him curious as to how it is created, where it comes from and where it goes. With the steady growth of general scientific knowledge over the centuries our understanding of weather processes developed. The recognition of the inter-relationship of such things as temperature, wind, atmospheric pressure, cloud and rain was a gradual but significant achievement. Nowadays much more is known about the behaviour of the atmosphere and, within the limits of such knowledge, efficient meteorological services now exist in most countries of the world.

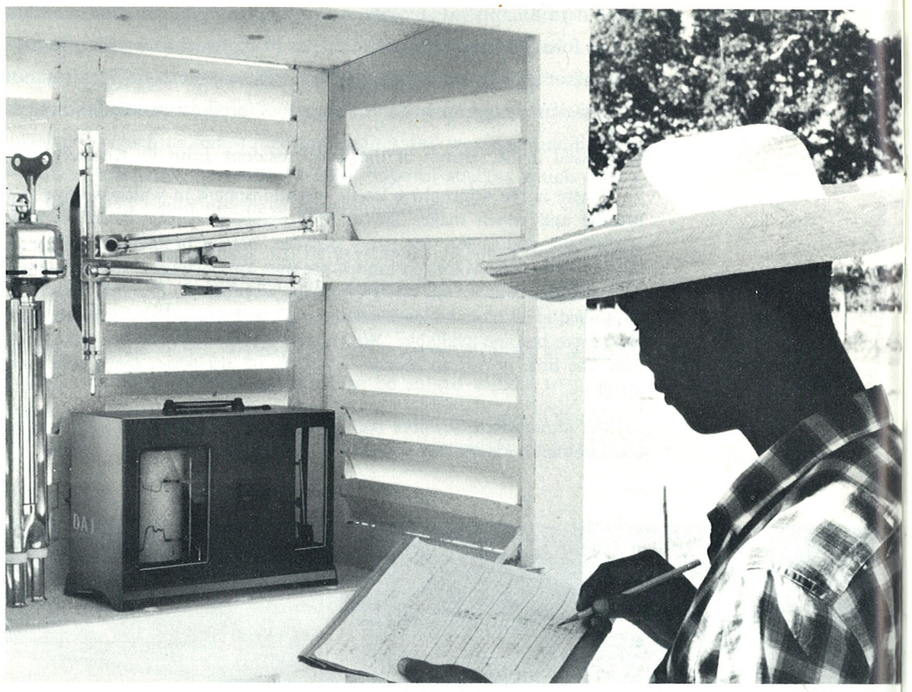
We are however still far from a complete understanding of the complex processes involved in the change and movement of weather systems and much knowledge still remains to be gleaned. But the stage has been reached where some of the major problems, as yet unsolved — such as long-range forecasting and weather modification — can at least now be studied with a hope of success which only a few years ago could not have been conceived.

International collaboration will be even more essential in the future than it has been in the past, for modern techniques require that information be obtained from greater and greater areas of the earth's surface and the World Weather Watch is now conceived as a global system. One of the main problems to be solved is how to observe the weather on a global scale. There is also the problem of establishing a global telecommunications system to ensure the collection of these data at appointed centres and their subsequent dissemination in one form or another to all countries of the world. Another important factor is that, unlike many other sciences, meteorology does not lend itself to experiments under a set of predetermined conditions.

Expressed in the words of the late President John F. Kennedy:

"... there is the atmosphere itself, the atmosphere in which we live and breathe and which makes life on this planet possible. Scientists have studied the atmosphere for many decades, but its problems continue to defy us. The reasons for our limited progress are obvious. Weather cannot be easily reproduced and observed in the laboratory. It must, therefore, be studied in all of its violence wherever it has its way. Here, new scientific tools have become available. With modern computers, rockets and satellites, the time is ripe to harness a variety of disciplines for a concerted attack.

... the atmospheric sciences require worldwide observation and, hence, international cooperation."



HOW WEATHER SERVICES DEVELOPED

While man's interest in the weather is as old as his ability to think, it was only about a century ago that the science of meteorology and the practical applications of the science on a significant scale may be said to have begun. The reason for this is that the meteorologist, unlike some scientists, cannot obtain the observations he requires by the touch of a button or by simply reading a set of instruments ; he clearly cannot himself observe the whole of his laboratory — the atmosphere — at one time. The observations made elsewhere must come to him, and they must come quickly if they are to be used for forecasting. The invention of the telegraph system in the first half of the nineteenth century made this possible. From that time onwards, weather reports from different places could be rapidly collected and up-to-date weather maps could be plotted.

Much of the early progress in the development of organized weather services was due to sailors, for in the days of sailing ships a good sailor had perforce to be a good meteorologist. It was in fact a violent storm in 1854 which sank British and French warships in the Black Sea and the subsequent awareness that the disaster could have been averted had news of the approaching storm been transmitted by telegraph to the port of Balaklava, which provided the stimulus

which led to the creation of national meteorological services in Europe.

It was also by the initiative of mariners that an international meeting on weather reporting was held in Brussels in 1853 ; this was the first international conference on meteorology to be held and may be said to mark the beginning of international meteorology as we now know it.

With the establishment of weather services, many improvements followed. Improved methods of observing the atmosphere were developed. Networks of meteorological stations on land appeared ; the use of merchant ships to obtain regular information from the ocean areas was introduced and later, in some regions, special ocean weather ships came into operation. The upper atmosphere was explored in a routine manner by balloons, kites and later by aeroplanes, radiosondes and rockets ; most recently, earth-orbiting satellites for observing the earth's atmosphere on a global scale appeared.

Nowadays there is no country in the world which does not have a national meteorological service and few in which investigational research work in some form or other is not being conducted. They all serve their respective countries ; they all contribute to and benefit from the world weather system.

TO-DAY'S WORLD EXCHANGE OF WEATHER INFORMATION

In any period of 24 hours about 100,000 observations of the weather conditions at the surface of the earth and about 11,000 observations of the upper atmosphere are recorded. These observations are made at some 8,000 land stations distributed among all countries of the world, on 3,000 transport and reconnaissance aircraft and 4,000 merchant ships.

These observations are made by day and by night at fixed times which are standardized throughout the world. In addition the elements reported (atmospheric pressure, temperature, humidity, visibility, cloud amounts, etc.), the methods and procedures used and even the order in which the readings of the different elements are made, all conform to internationally agreed practices. To this vast volume of data must be added the information now becoming available from meteorological satellites and rockets.

The observations are collected by a network of national, regional and continental centres and are then retransmitted as collective messages to all countries. It is this information which constitutes the basic information plotted on weather maps throughout the world. Such maps are generally prepared at six-hourly intervals (and sometimes

more frequently) and they are the means of analyzing existing weather situations and of preparing weather forecasts for all purposes — agriculture, aviation, shipping, etc. A meteorological telecommunications system covering the whole world has therefore been developed to ensure the prompt collection and dissemination of this basic weather data.

Worthy of special mention is the system developed for a speedy and selective exchange of meteorological information in the Northern Hemisphere involving five main collection and transmission centres at Moscow, New Delhi, New York, Offenbach (Germany) and Tokyo.

WHY THE PRESENT SYSTEM NEEDS IMPROVING

The system of weather observing and exchange described above demonstrates the importance of weather information in the modern world and is indeed quite a remarkable example of international co-operation ; it is nevertheless incomplete and deficient in many ways as regards the means of observing the atmosphere and the international exchange of the data so obtained. The main deficiencies are as follows :

— In the Southern Hemisphere, 75% of which is covered by oceans, weather observations, both at the earth's surface and in the upper-air, are very inadequate. Facilities for exchanging observations within the Southern Hemisphere also need urgent improvement.

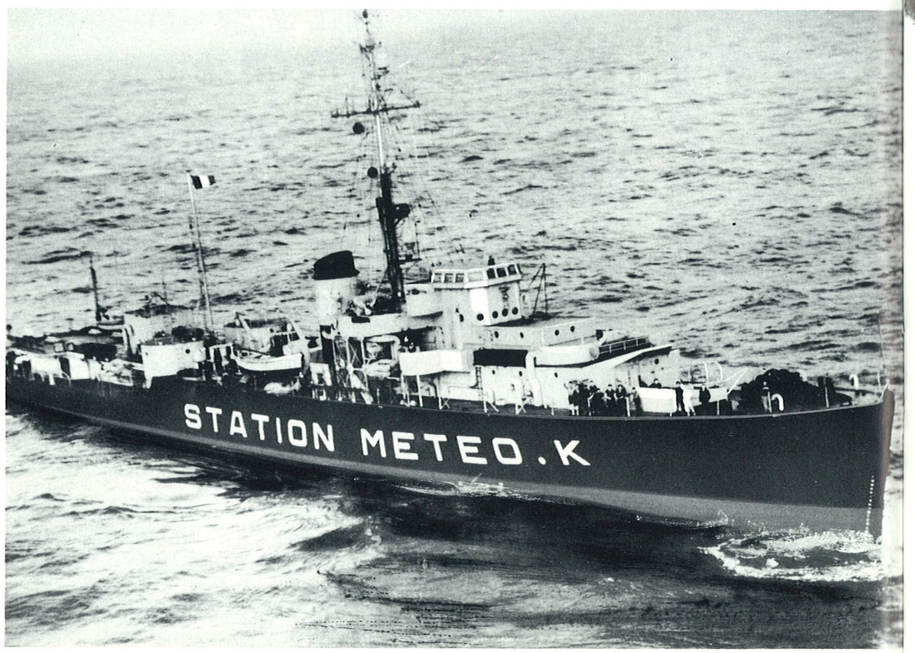
— Information regarding the upper layers of the atmosphere is insufficient all over the world. This information is essential, not only for forecasting (in particular for aviation), but also for a better understanding of the processes of the atmosphere. Satellite photographs of cloud formations have already revealed phenomena in the upper-air which had not been observed at all by routine balloon ascents and have thus demonstrated how scanty our upper-air observation network is.

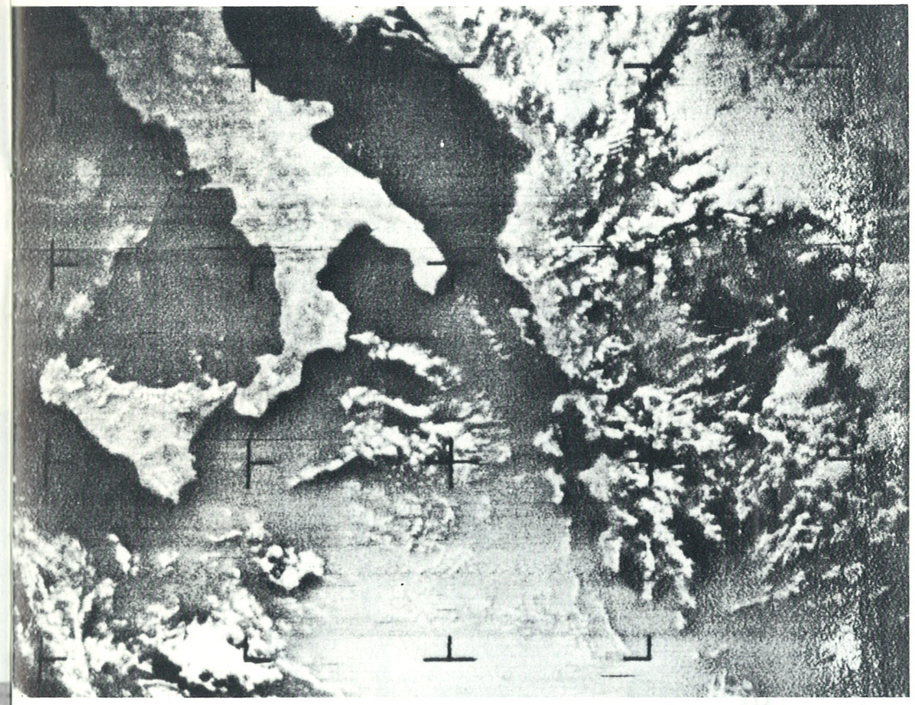
— The usefulness of the weather information received by the forecaster depends to a very large degree on how quickly he obtains it ; therefore speed of transmission of weather observations is an important problem. To improve forecasting the international exchange of weather reports must not only be extended to obtain more information, but must also be speeded up.

— The progress in the science of meteorology made possible by the system of exchange of data so far developed has demonstrated that there is a relationship between weather phenomena in the Northern and in the Southern Hemispheres. In particular, efforts to extend the range of forecasting to several days or even a month have shown that further progress in this direction can only be achieved if information from both hemispheres is constantly available to the forecaster. Thus the prompt exchange of data between the two hemispheres is required.

— The need for weather information has increased very greatly because of world wide recognition of the benefits which it can provide to economic development. Agriculture, water utilization, transportation, etc. are all important aspects of economic development and all depend in one way or another on weather and climate. The present system does not enable the maximum assistance to be given in these fields.

How can these deficiencies be rectified and so enable a world system to be introduced capable of meeting present day needs more effectively ? Fortunately, several new tools have become available for observing and analyzing the weather — they include artificial satellites, high speed electronic computers, automatic weather stations and meteorological buoys. Fortunately also, new telecommunications techniques are constantly being developed and are becoming available for meteorological purposes.





THE NEW TOOLS

SATELLITES

The artificial earth-orbiting satellite is a new means of observing the weather ; it presents two important advantages over all other known techniques :

(1) It provides a means of observing the weather from outside the atmosphere ;

(2) It provides a means of providing weather information promptly and on a truly global scale.

Meteorological satellites which have so far been used have carried ingenious devices for observing the atmospheric conditions. They include such items as television cameras which take photographs of the earth's surface and which hence reveal the cloud formations ; such cameras incidentally also provide supplementary information such as snow cover over land masses and floating ice over sea areas. They may also be equipped with instruments for making various kinds of radiation measurements in the infra-red band which reveal

the temperature of the land or cloud layer immediately below the satellite and thus enable cloud areas to be detected ; moreover this system may be used at night for detecting cloud systems during darkness when normal photographic methods cannot be used.

The meteorological satellite may also be equipped with sensitive photometric devices which measure by optical means the brightness of the earth's surface, enabling cloud areas to be detected.

Initially all the observations had to be stored in the satellite until transmitted on command to a major read-out station with its vast array of telecommunications equipment but a later development made it possible for photographs to be transmitted on a continuous basis and to be received in any country over which the satellite is passing, by means of relatively simple and inexpensive ground equipment. This important new development, which is known as Automatic Picture Transmission (APT), will mean that direct reception of weather information in the form of photographs covering an area of a radius of 1600 kilometers around the receiving station will be within the reach of every country of the world. In other words each country, whether large or small, will have the possibility of participating directly in the space age. Many countries are in fact already equipped with APT receivers.

Another important advantage of the APT system is that it will simplify the arrangements which would otherwise have to be made for transmitting such information from one or other of the few major read-out stations to each country, for, as will be seen later, the new World Weather Watch aims at ensuring by one means or another that the benefits of such new and exciting devices shall be shared by all countries of the world.

The use of satellites for practical meteorological purposes is moreover not simply a hope for the future. Useful satellite data has in fact been received continuously from the very successful series of TIROS satellites of the United States, the first of which was launched in 1960. Moreover, these data have since the beginning been made available internationally to all countries by radio broadcasts, details of which have been distributed by WMO to all countries.

It must be noted however that the interpretation of the information obtained from meteorological satellites is a very skilled operation and requires specially trained personnel. The detection of the main cloud masses is of course not difficult but a skilled scientist can deduce much more than this from the satellite photographs. The type and

height of cloud, the wind direction and even the jet stream * may be detected. Similarly the interpretation of other data (infra-red and photometric) can only be undertaken after special training. Thus while the benefits of meteorological satellites are already being made available to all countries and will continue on an increasing scale, each country needs to give attention to the training of meteorologists skilled in the interpretation of the data received.

Despite the remarkable progress which has been made in the design of meteorological satellites, further developments are envisaged. A means of detecting the variations of temperature in a vertical direction through the earth's atmosphere is one. The use of satellites to collect weather reports from land-based automatic weather stations or similar stations mounted on buoys floating on the oceans of the

* This is the name given to a narrow band of very strong wind which frequently occurs in temperate latitudes at heights of about 10,000 m and which is of great importance for aviation and general forecasting purposes.

world is another. The use of satellites as a communications device for exchanging weather data between the countries of the world is yet another. While accurate forecasts of the final means of utilizing satellites in the future are impossible to make, it is quite clear that the advent of meteorological satellites marks a turning point in the science of meteorology and that their use will figure prominently in the World Weather Watch plans now being developed.

COMPUTERS

In 1922 a British mathematician, Lewis Fry Richardson, put forward the idea of predicting the weather by numerical methods. This idea was based upon the fact that the changes in the atmosphere follow dynamic and thermo-dynamic laws which are well known and understood and that if the state of the atmosphere at any time were known, then by applying these laws the state at any future time could be calculated. The laws themselves are however very complex in their practical application but if applied in a simplified form over a short period (normally one hour) and if the process is then repeated many times, weather predictions for useful periods ahead could be made.

There were initially two main difficulties to the application of Richardson's idea. In the first place the amount of atmospheric data available was far too scanty to make the method feasible. The situation in this respect has of course improved enormously since that time but, as already explained, the need for an improved global observational system is still great. Fortunately, some very promising methods have recently become available.

The second reason why Richardson's idea could not be applied at that time was because the calculations involved were far too great to enable useful results to be made with any known method of making the calculations. To have translated Richardson's theories into practice would at that time have required 64,000 mathematicians to predict the global weather on the basis of data from 2,000 stations sufficiently rapidly to keep pace with the weather.

The advent of the high speed electronic computer has however enabled the theories of Richardson to be converted into practical forecasting techniques which are now used on a routine basis in many countries of the world. Indeed numerical weather prediction is now recognized on all sides as a technique which opens up important new possibilities for forecasting the weather.

With the latest computers, the basic observational material from all parts of the world may be processed within a few hours and prognostic

weather maps up to 72 hours ahead produced. Up to the stage of producing the prognostic weather maps the methods are entirely objective, with the computer not only processing the data but also checking each individual report, rejecting some reports and even indicating the reason why the report has been rejected. The forecaster has then to take over and interpret the weather map by subjective methods into specific forecasts of rain, cloud, etc. Research is being conducted in many countries with a view to extending the range of the forecasts so produced and also with a view to obtaining predictions of rain and cloud and other meteorological elements from the computer itself.

It is hardly surprising therefore that centres equipped with electronic computers will figure very prominently in the World Weather Watch plan now being prepared.

WORLD WEATHER WATCH

The term "World Weather Watch" has already been used many times in this brochure and it is now necessary to explain more clearly what it means.

World Weather Watch is the name given to a new world weather system which WMO is now planning. There is, of course, already a world weather system in operation which has been developed gradually over the last 90 years or so. Some of the main features of this system, such as the means of observing the earth's atmosphere and the international exchange of the data so acquired, have already been described. As new techniques and procedures have evolved so the system has been modified over the years.

Why then is there need for a new system with a new name? Why cannot the present system be adjusted to meet new developments as has been done in the past? The answer to these questions lies in the fact that the new methods and devices which are now available are not simply new developments in the sense that there have been developments in the past. They are much more significant and far-reaching in their consequences. Indeed they open up such tremendous new possibilities for improving man's knowledge of the atmosphere in which he lives and of applying this knowledge for the benefit of all countries of the world that they must be regarded as marking a turning point in the science of meteorology. Their introduction calls therefore not for a simple adjustment to an existing system but rather a reappraisal and redesign of the system as a whole. A fresh look must be taken at what the system will need to produce and how it can do so in the most efficient manner.

This in turn means that the various components of the system must be studied in detail, bearing in mind at all times the need to ensure that the benefits of the scientific and technological advances in the field of meteorology must be passed on to all countries of the world and that the information made available must serve both practical and research purposes.

In the first place a new plan for observing the earth's atmosphere on a truly global scale must be developed. A study must then be made of the telecommunications system for exchanging this information in its original form or in some processed form. The greatly increased volume of data which is now becoming available, including that from satellites, has made it necessary to develop the concept of special centres for collecting and disseminating the data and it has already been decided that a system of world, regional and national centres shall be established, each of which is receiving, processing and distributing information in accordance with a prearranged plan. Thus the

plans for World Weather Watch which are now being prepared may be divided into three broad categories—the Global Observational System, the Global Telecommunications System and World Weather Watch centres of various kinds. These three aspects of the planning activities are described in more detail in the following paragraphs. Before turning to this, some information on the timing aspects of the planning activities seems desirable.

The planning of a world system of the kind described is a task of great magnitude and complexity. In order to ensure the orderly and systematic development of the plans, the work has been divided into three phases. The first phase, which concerned the establishment of the broad lines of World Weather Watch was completed in the middle of 1965. Phase II calls for the preparation of a world plan in a more or less complete form and will be completed in the middle of 1966. Phase III involves the completion in full detail of the plan which must be ready for submission to the representatives of the countries of the world at the Fifth World Meteorological Congress in 1967. Many countries have already taken important steps in anticipation of the formal approval of the World Weather Watch plans. And in this sense the implementation of WWW may be said to have already begun.

THE GLOBAL OBSERVATION SYSTEM

The largest single obstacle to a full scientific understanding of our atmosphere is the lack of adequate weather observations from the entire globe. Little real progress in improving the accuracy of weather forecasts, or in extending their period of validity, is likely until this shortcoming is remedied.

At present less than one quarter of the surface of the globe has sufficient meteorological stations. Even over those land areas where the density of surface weather reports is adequate, the number of stations making soundings of the upper atmosphere is frequently too small or their observations fail to reach the desired heights. As regards the oceans, valuable reports are received from ships plying the world's trade routes, but for the most part the oceans yield little or no meteorological information. This means that over most of our planet we do not know the structure of the atmosphere in sufficient detail to understand the physical processes taking place at any given moment. Since current methods of weather forecasting start from a knowledge of actual weather conditions the implications of this ignorance are evident.

The development of a truly global observation system presents one of the most exciting challenges of the World Weather Watch and at

the same time a problem of enormous dimensions. It is a problem that calls for a bold and adventurous approach. How will it be met?

The gaps in the continental networks of stations reporting surface conditions must be filled by new stations and, more urgently, the number of radiosonde stations must be greatly increased, notably in the developing countries. In a few parts of the world the problems cannot be overcome by conventional methods and the completion of the surface network may only be achieved when suitable automatic equipment can be installed.

Over the oceans different solutions must be found and it is here that the full resources of scientific ingenuity and skill must be employed. Conventional observations taken at sea level aboard merchant ships must evidently be increased; and in addition, if the large-scale introduction of radiosonde observations on these vessels could be arranged, a considerable improvement in the present upper-air net-

work would result. But these methods alone will by no means solve the problem of sampling the atmosphere over the vast empty reaches of ocean where no ship sails.

Several new methods are fortunately available or are being studied to fill these gaps on land and sea. In the first place the meteorological satellite has already demonstrated beyond any doubt its unique and unprecedented capacity for obtaining certain types of weather information on a truly global scale. By means of television cameras and infra-red sensors the cloud patterns covering the earth can be detected and from this information much can be learned about the weather systems and their movement and development. These valuable functions, which have given us the first global view of the world's weather, will certainly be extended in the future. Spectrometers and other new devices, perhaps including lasers, will enable satellites to be used for vertical sampling of temperature and other elements. It is clear that within a few years space techniques will have to play a leading role in the new observational system.

Other methods used to complete the system will include special aircraft reconnaissance flights as well as reports from commercial aircraft. The use of dropsondes — radiosondes which transmit observations as they descend on a parachute after release from an aircraft — is likely to become more widespread. Meteorological rockets and ocean weather ships will also play their part.

Many of these projects are still experimental and the final mixture of observing techniques will evidently depend on many factors, not least the cost and efficiency of each type in different parts of the world. Whatever the choice, meteorology stands on the threshold of a new era as the result of the rapid developments in space technology and advances in electronics, with the promise of considerable benefits to be reaped from the money and effort expended upon the global observing system. Its effect on the lives of each of us could well be profound.

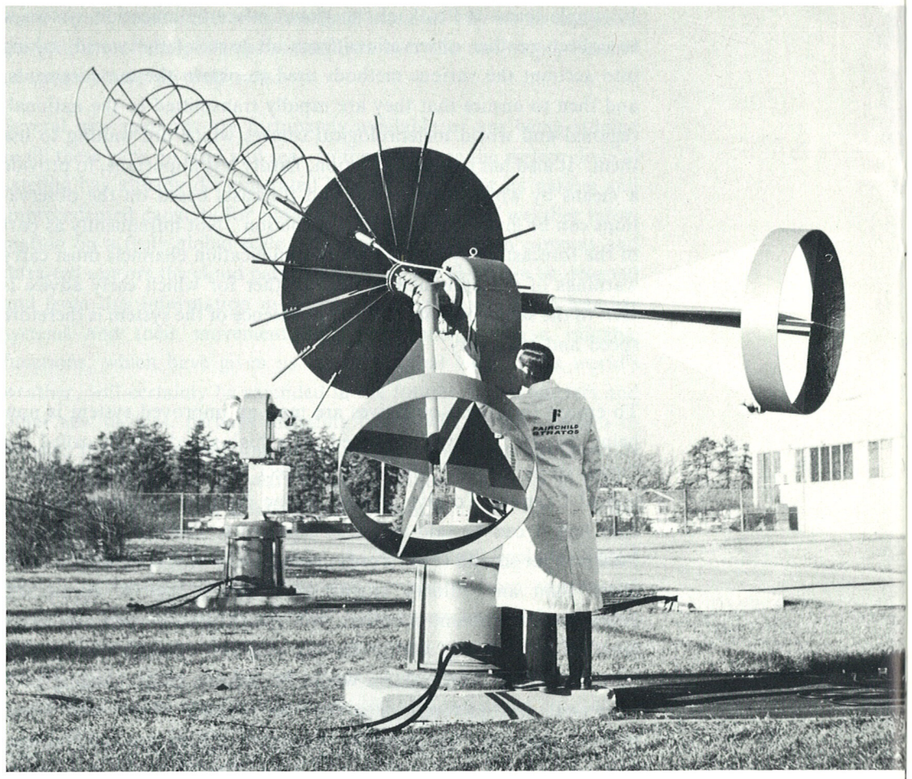
THE GLOBAL TELECOMMUNICATION SYSTEM

The prime importance of observing the atmosphere on a world-wide scale never before attempted was described in the preceding section. But the effort and money devoted to this end will be of little avail unless it is effectively supported by a speedy and reliable system for the collection and distribution of the resulting data. For this reason the development of a telecommunication system capable of handling a greatly increased quantity of material must go hand-in-hand with the other measures planned as part of the World Weather Watch.

In simple terms the task of the global telecommunication system is to collect weather observations from all parts of the world, taking into account the various methods used to obtain the measurements, and then to ensure that they are rapidly transmitted to the national, regional and world meteorological centres which are waiting to use them. It also has a second function, hardly less important, to provide a means by which the analyses and forecasts based on the observations can be given the required distribution. Not infrequently as part of the forecasting system the telecommunication channels must carry warnings of the approach of bad weather for which early advice is vital to the safety of human life. The essence of the system is therefore speed and reliability.

To ensure that these objectives are met, an improved system is now being designed. It will be based on a high-speed circuit called the "main trunk circuit" which will connect the three World Meteorological Centres. To give an idea of the capacity of this high-speed data link it can be said that it is expected to operate at a speed of 2400 bits per second (3600 words per minute) which is almost 50 times faster than an ordinary teleprinter. Such a system, connecting computers in different countries, will span the continents and make possible the exchange and processing of a vast quantity of data in a very short time. The system would be capable of exchanging both numerical and pictorial data such as weather charts and cloud pictures accurately and speedily. A number of Regional and National Meteorological Centres will also be linked directly to the main trunk circuit. The need for adequate telecommunications to bring material to and from the points connected to the main trunk must also be considered. In designing the complete system the fullest possible use will therefore be made of cable and land-line circuits or other telecommunication methods with similar technical and operational characteristics.

The revolution in technology which inspired the World Weather Watch will also have an impact on the Global Telecommunication System. Developments now taking place in satellite technology will result in significant improvements in telecommunications, making much higher transmission speeds possible at greatly reduced cost. Among the exciting possibilities created by the advent of space techniques are spacecraft in orbit around the earth equipped to locate and interrogate manned or unmanned weather stations, including buoys and floating balloons. The observations obtained in this way will either be read out to selected ground command stations or broadcast for reception by a number of stations.



During the initial stages of the World Weather Watch these new techniques will not be available and existing methods will have to be relied upon. They will undoubtedly take their place in the Global Telecommunication System once their full potential has been established.

WORLD METEOROLOGICAL CENTRES

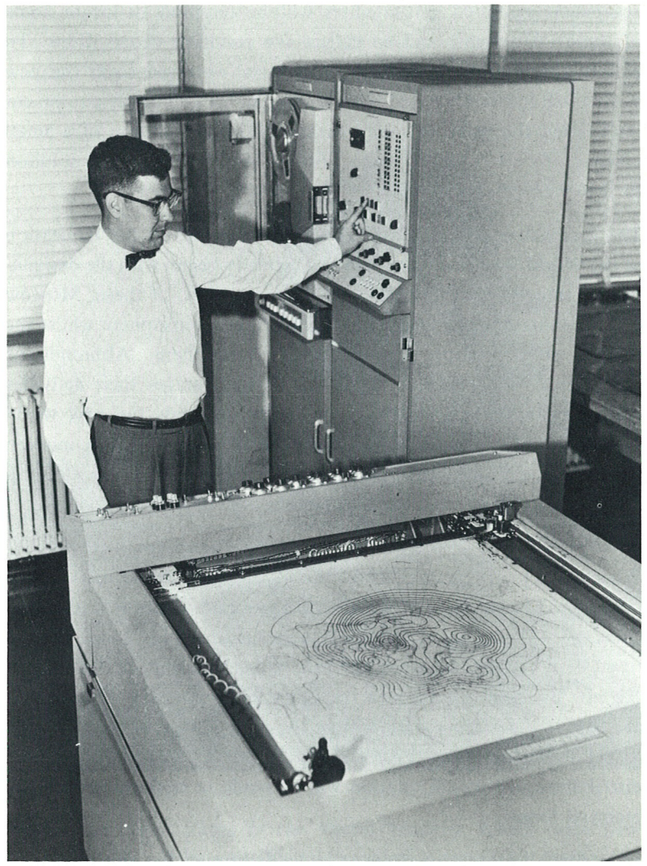
It may be asked why World Meteorological Centres are essential to the World Weather Watch. To answer this question it is necessary to look ahead and visualize the future observational system. As has already been described this will involve the use of new techniques including satellite-borne sensors, drifting and moored buoys in the oceans and automatic weather stations in desert and other uninhabited areas ; constant-level balloons at various heights are also amongst the new devices which may be used for sampling the state of the atmosphere on a truly global scale. It is likely that telecommunications

equipment mounted on satellites will be required to locate some of these instruments and to collect the resulting observations. To collect and process the wealth of material obtained from the new system will inevitably entail the use of complex and costly equipment far beyond the reach of many nations. The designation of a small number of centres to serve the world is therefore a logical solution to this problem.

The establishment of the special centres essential to the realization of the World Weather Watch plan has already begun with the designation of three World Meteorological Centres. Two of these, Moscow and Washington, are situated in the Northern hemisphere whilst the third is at Melbourne in the Southern hemisphere. Although the operation of these centres is only in its early stages their activities will gradually expand to meet the heavy demands the new world system will place upon them. They will be equipped with modern high-speed electronic computers and telecommunication facilities adequate for the reception and distribution of weather data on a global scale.

What is the job of these centres ? Firstly they should receive conventional and satellite data from all over the world. In general the data collected will provide a global weather picture either twice or four times daily, depending upon the type of information, and will form the raw material upon which the other functions of World Centres are based. The second task will be the relay of appropriate material to other world, regional and national centres. The collection and distribution of this information will be made in both numerical and pictorial forms.

In addition to these functions as a clearing-house for global weather information, each World Meteorological Centre will have important responsibilities for the preparation of analyses of prevailing weather conditions and prognoses. This work will be concentrated on large-scale weather features, often over an entire hemisphere, and will extend from the earth's surface through different levels of the atmosphere to a height of about 30 km. These "output products" will be tailored to meet the needs of national Meteorological Services and so to assist them in making the most efficient use of their own resources in applying meteorological knowledge to national activities. The analyses will be issued at least twice daily whilst, depending on their period of validity, the prognoses will be issued once or twice a day. They will in due course be for periods of up to four days ahead, and in some cases even to five days or longer. The meteorologist receiving these large-scale analyses and prognoses will be in a better position than ever before in making his local forecast of the weather and



it is hoped that the greater accuracy so vital to many users will be achieved. Full use will also be made of the most advanced satellite techniques in providing early warning of important weather phenomena.

This brief description of the chief functions of World Meteorological Centres is clearly not exhaustive. Whilst further experience will undoubtedly reveal many other ways in which they can provide valuable services, it is already evident that they will be well placed to play their part in the promotion of research and training as well as in serving as archives for the vast quantities of data passing through them. These duties have, however, yet to be defined. Even so, it is certain that their broad responsibilities as global centres for the collection, processing and distribution of meteorological information will make them the pivots about which the new system will revolve.

REGIONAL METEOROLOGICAL CENTRES

It is a fundamental principle of the World Weather Watch that it must be designed to support the weather services of individual nations. It would however be impractical and inefficient to expect World Meteorological Centres to serve the detailed and widely different needs of every nation, and yet the new system will fail unless it is able to meet these needs. A system of Regional Meteorological Centres is therefore planned to provide a vital link between world and national centres. Neither the locations nor the precise functions of Regional Meteorological Centres have however yet been finally decided.

The practical responsibilities of individual Regional Meteorological Centres will vary enormously, depending upon such factors as the level of development of the countries they serve and the physical and climatic characteristics of the region. However some of the useful duties they can carry out are already plain. For example, in the years immediately ahead, relatively few national meteorological services will have computers of their own. Regional Meteorological Centres will be so equipped and should provide computer facilities for the regions they serve. Analyses and prognoses of both surface and upper-air conditions which should help national centres to prepare more accurate forecasts will be issued and basic meteorological information will be processed and stored. Selected data will be published, and both training and research in the atmospheric sciences will be supported by these centres. In some cases the principal functions of Regional Meteorological Centres will be the collection, checking, processing and redistribution of basic weather information. In others the duties will be confined to the operation of telecommunications facilities, in which case they will be termed Regional Telecommunications Hubs.

Whatever the ultimate variety of responsibilities of regional centres, raw data for the whole of the hemisphere in which they are located is likely to be channelled through them. They will also receive global or hemispheric analyses and forecasts from the World Centres to which they are linked. They will work in close association with the National Meteorological Centres in their sphere of operation, both by providing them with the material they need and also by serving as centres through which incoming observations are fed to the world centres. The active participation of national meteorological services in adequately equipping and staffing National Meteorological Centres will be essential if full benefit is to be derived from the new world meteorological system.

BENEFITS EXPECTED FROM THE WORLD WEATHER WATCH

To describe the benefits which may be expected from the World Weather Watch would in effect involve a review of all the many applications of meteorological knowledge and an estimate of the improved services which World Weather Watch will provide in each case. To do this would require much more space than would be reasonable to allocate in a booklet of this kind. Indeed a separate booklet on the application of meteorology to human activities, entitled "Weather and Man", has already been produced by the World Meteorological Organization.

Nevertheless an account of World Weather Watch would not be complete without some reference to the subject of benefits, for they will undoubtedly be real and substantial.

The benefits will result from two main factors which are in fact inter-related. In the first place, the improved observational system of World Weather Watch and the arrangements for collecting, processing and re-distributing the observational data will result in an improvement in the existing services, especially forecasting services, which each national meteorological service will be able to render at the national level on the basis of present knowledge of the atmosphere.

Secondly, the new system will facilitate greatly research into the atmospheric processes and this will in due course lead to improved techniques for forecasting the weather and possibly even useful methods of modifying the weather.

LONG-RANGE FORECASTING AND WEATHER MODIFICATION

Let us take first the question of weather forecasting. Man has for centuries endeavoured to foretell the weather and to use the forecasts for his benefit and protection. It is however only in relatively recent times that meaningful forecasts have been available. The reasons for this have already been described. But even now despite the quite remarkable progress which meteorology has made in the last 50 years or so, accurate and detailed forecasts for more than 48 hours ahead are still not available on a routine basis in most countries of the world. Certainly some countries issue weekly or monthly outlooks of the weather and great skill and knowledge have gone into the development of techniques for producing such forecasts. While these are of undoubted value, it must be admitted that forecasting and especially long-range forecasting still falls short of what might be regarded as an attainable goal — although without more basic knowledge of the atmosphere even the definition of an attainable goal is difficult !

What is the situation regarding weather modification ? Man has hitherto been obliged to accept the weather and climate that nature produces. By applying his intelligence and knowledge over the centuries he has in modest ways been able to adapt conditions for his

protection and benefit. He wears clothes and constructs buildings in order to produce artificial microclimates around him. He collects rainfall in reservoirs and uses the water to irrigate his crops when natural rain is insufficient. He plants trees to act as shelter belts for agricultural purposes. He has devised various means of protecting crops against frost — and so on. What more can he do ?

There are two distinct aspects of this problem, namely modifying weather and modifying climate. The first implies the use of artificial means to modify the weather conditions at a particular time and place — for example, to make a cloud formation produce rain when it would not otherwise do so ; to disperse a particular bank of cloud or fog ; etc. The second implies action taken to modify permanently the climate of a whole country or region. For example to modify the climate of Europe by diverting in some way the Gulf Stream further to the north.

Many experiments on the artificial stimulation of rain have been conducted in recent years. In brief these have shown that in certain circumstances, especially near mountain ranges, claims of a small increase in rainfall appear to be justified but elsewhere the results are for the main part inconclusive. Techniques for the dispersion of fog and some types of cloud on a limited scale are however further advanced.

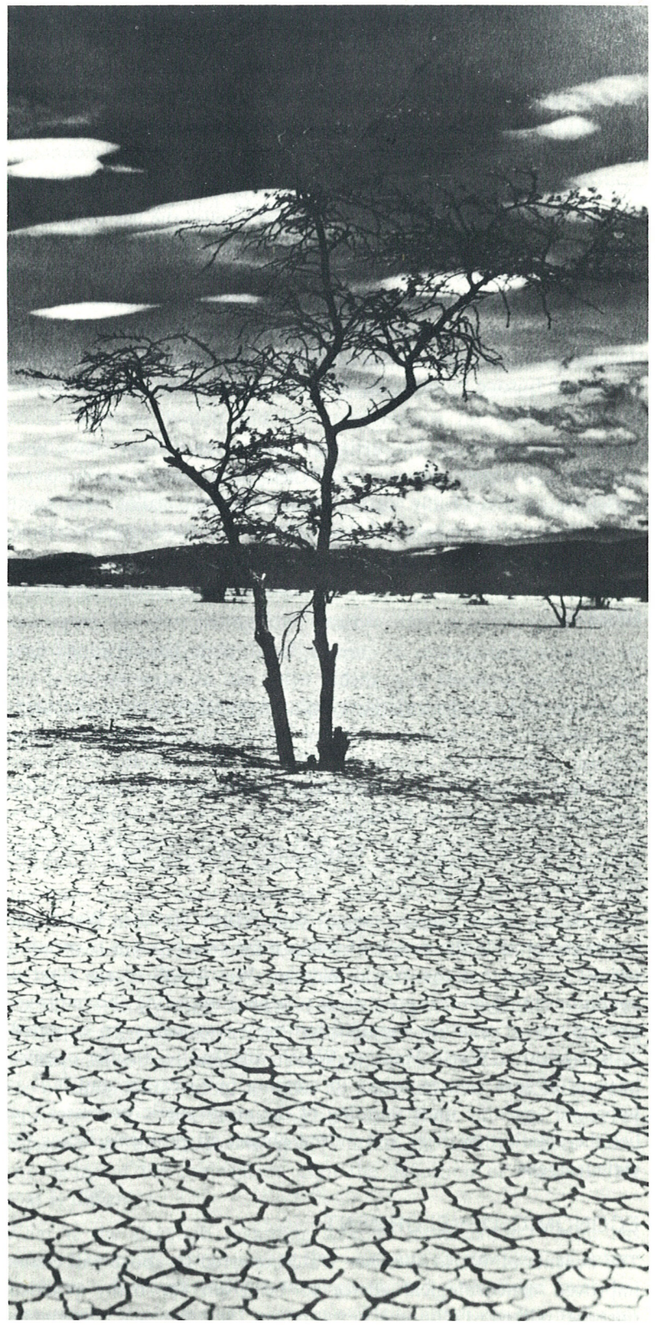
As regards modification of climate, small scale modifications have already been achieved (e.g. shelter belts) but no experiments of any significance on a large scale have been as yet attempted and certainly none should be undertaken without full scientific investigation and without international agreement. The risk of producing an irreversible and adverse affect which might affect many countries must evidently be avoided at all costs.

How will the World Weather Watch affect these problems of weather forecasting and modification ?

It would be misleading to suggest that World Weather Watch will overnight provide the means of doing these things but it is certainly correct to say that the World Weather Watch will create a set of conditions in which real progress in weather forecasting and improved possibilities of weather modification may reasonably be expected. This is because World Weather Watch will lead to a fuller comprehension of how nature works in creating our weather and it is in improved scientific understanding of the atmospheric processes that lies the solution to these and indeed almost all problems facing the meteorologist.

ECONOMIC DEVELOPMENT

The benefits of World Weather Watch referred to above will enable improved meteorological advice to be given for many practical purposes related to economic development. It is however not possible



to give detailed discussion of the present and future applications of meteorology to economic development in this booklet but some brief comments are given for purposes of illustration. Two other booklets published by WMO give much information on this subject : "Weather and Food" and "Weather and Man".

With regard to agriculture the two publications just mentioned demonstrate that there are many ways in which knowledge of weather and climate assist in this very fundamental human activity ; it is to be expected therefore that World Weather Watch will have a significant impact in this field. For example, improved forecasts, especially long-range forecasts, would be of great benefit to those who plan the whole cycle of agricultural operations.

These publications also show that climatic data, coupled with a knowledge of the present weather and of the forecasts of its future course can help to solve a host of other problems :

— the choice of crops, animal husbandry methods that will give an impetus to profitable agricultural development.

— determination of favourable periods for sowing, making hay and harvesting.

— provision of shelter from wind, drifting sand or snow, and frost protection.

— planning of afforestation and irrigation to supplement inadequate rainfall or to increase crop output and profitability.

— control of crop hazards, such as potato blight, wheat rust, etc. by chemical spraying when damaging weather is expected.

— control of the desert locust. As moisture stimulates hatching and swarms move with the wind, meteorology plays an important part in the anti-locust war.

In the field of water resource development meteorological information is no less essential. For the planning of all major projects involving the large-scale utilization of water, adequate data of rainfall and run-off and, in some cases, evaporation, is essential. Without such data costly projects such as the construction of dams, may not produce the anticipated benefits or, on the other hand, may be inadequate to utilize to the full the natural water resources.

In the field of transportation, the importance of meteorology to aviation and shipping is too evident to need stressing and improved forecasts will enable improved services to be rendered in both cases. It may be mentioned that new developments in aviation, such as the introduction of supersonic aircraft, make it essential for improved meteorological services to be provided.

In industry and commerce meteorological information is also important in innumerable ways ; the following are just a few examples : industrial pollution of the atmosphere, transportation of perishable goods by sea and by land, fluctuations in electricity requirements in warm and cold weather, air-conditioning installations, etc. etc.

TYPHOON AND HURRICANE WARNINGS

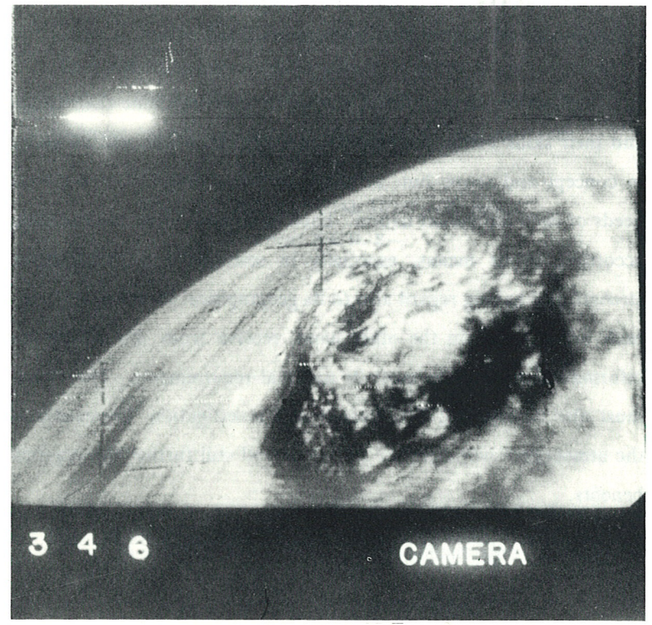
The catalogue of weather disasters contains few events more devastating than the onslaught of a typhoon or hurricane. Attempts are being made to temper the fury of these storms by artificial means but these have so far been inconclusive ; early and accurate forecasting of their subsequent development and movement detection still remain the only ways of enabling human life and property to be protected.

Fortunately new tools such as long-range storm warning radar and, more especially, weather satellites have simplified these tasks. By means of radar the storm may be detected up to distances of the

order of 300 kilometers while movement of the storms may be watched continuously. The value of this device for giving warnings is evident. As regards the satellite, the global surveillance it provides renders it an invaluable new means of detecting and following such devastating phenomena. Since 1961 more than 130 severe storms — typhoons in the Pacific, cyclones in the Bay of Bengal and the Indian Ocean and hurricanes in the Atlantic — have been detected and tracked by satellites at a much earlier stage in their development than would have been possible with any other known method. By analyzing satellite cloud photographs, meteorologists may even estimate the maximum wind speed of such storms.

The World Weather Watch, with its operational satellites, improved observation network and speedier exchange of information, will provide earlier and better warnings of severe storms on both a local and a global scale. Timely warnings of impending calamities will help to minimize losses by enabling precautionary measures to be taken.

While it is difficult, if not impossible, to assess the lives and property that might be saved by an improved warning system, there seems little doubt that the potential benefits from a world-wide warning service would far outweigh the cost of establishing it.



CONCLUSION

Weather is of concern to each individual and each nation. It is impartial in its favours and in its anger. It smiles on developed as well as developing nations ; its disasters fall without discrimination on industrialized and agrarian lands alike.

To reap the benefits of favourable weather and to minimize the dangers of severe weather, the countries of the world have long recognized that they must work together. Moreover, to meet the needs of modern times in economic development and human welfare, the beneficial applications of weather knowledge must be expanded, while protection and precautions against severe weather must be improved.

Fortunately modern needs for improved services can be matched by modern scientific developments if these are rightly applied. The tools now exist for obtaining an understanding of the atmosphere and its ways such as only a few years ago could hardly have been conceived. But a world effort will be needed to achieve this and the effort will need to be applied in a coordinated and systematic fashion to ensure maximum benefits from the facilities provided.

In other words, the nations of the world must combine their efforts and their skills within a single weather system, which will be global in concept and scope but, at the same time, designed to meet the needs of each individual nation. Each nation will need to contribute according to its means, especially in scientific and technological strength and having regard also to its geographical location and area ; each nation will, on the other hand, receive from the system the information it needs to meet its national requirements. The system must also ensure that by research and investigation, knowledge of the atmosphere will advance and so extend still further the practical benefits.

To plan and implement such a system is the purpose of

WORLD WEATHER WATCH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